MN-CR SYSTEMATICS OF DIFFERENTIATED METEORITES. Weibiao Hsu, Gary R. Huss and G. J. Wasserburg, The Lunatic Asylum, Division of Geological & Planetary Sciences 170-25, Caltech, Pasadena, CA 91125. (whsu@gps.caltech.edu)

We report on a study of Mn-Cr isotopic systematics in three pallasites and one aubrite carried out to seek additional evidence for the abundance of ^{53}Mn in these planetary differentiates. Previous workers have shown evidence for the presence of ^{53}Mn in a variety of meteoritic material ranging from CAIs to eucrites, iron meteorites and pallasites [1-4]. The mean life of ^{53}Mn ($\tau=5.3\times10^{6}$ Ma) is sufficiently long that it should persist through the period of early planetary differentiation. However, the ^{53}Mn-^{53}Cr system is distinct from the ^{107}Pd-^{107}Ag and ^{187}Re-^{187}Os systems whose behavior is governed by metal phases and is not sensitive to thermal metamorphism. In contrast, the ^{53}Mn-^{53}Cr chronometer is subject to the local redistribution of parent and daughter elements between a variety of phases during cooling. Excesses of radiogenic ^{53}Cr (^{53}Cr*), correlated with Mn/Cr ratios, have been found in some IIIAB irons [3]. The inferred initial ^{53}Mn/^{55}Mn ratio ((^{53}Mn/^{55}Mn)$_o$) is found to vary widely (8×10^{-7} to 2×10^{-5}) in these meteorites [3], which suggests a time interval of ~15 Ma, whereas the Pd-Ag data indicate a time less than 10 Ma [5]. The metal phase of pallasites is chemically similar to IIIAB iron meteorites and is the result of planetary differentiation [6]. The pallasites, Springwater and Eagle Station, were previously reported to have (^{53}Mn/^{55}Mn)$_o$ Å 1.4×10^{-5} and 2.3×10^{-6}, respectively [2,3]. To confirm these results, to seek additional evidence of ^{53}Mn in differentiated meteorites, and to test possible relationships with other short-lived nuclide chronometers, we investigated the Mn-Cr systematics of the Albin, Brenham, and Springwater pallasites and the Norton County aubrite. The isotopic effects we are seeking are, by necessity, much larger than those reported by [4] and we have no hope of resolving the small differences in initial Cr composition that they observed.

The Cr isotopic compositions of olivine, troilite, and chromite in the pallasites and of alabandite and daubreelite in the aubrite were analyzed with PANURGE, a modified IMS-3f ion microprobe. An $^{16}O^-$ primary beam was used and the measurements were carried out at a mass resolving power of ~ 6000, which eliminated almost all molecular species. We sought to determine instrumental mass fractionation during each measurement using the ^{50}Cr/^{52}Cr ratio. $^{49}Ti^+$ and $^{51}V^+$ were monitored to permit corrections for unresolved isobaric interferences at mass 50 by $^{50}Ti^+$ and $^{50}V^+$. Contributions from $^{50}V^+$ are negligible, but corrections for $^{50}Ti^+$ are 10 to 30 ‰ of the $^{50}Cr^+$ signal in pallasite olivine. These large corrections for ^{50}Ti resulted in variable ^{50}Cr/^{52}Cr ratios, which therefore could not be used to correct for instrumental mass fractionation. Terrestrial Cr-diopside and San Carlo olivine yielded reproducible ^{50}Cr/^{52}Cr, so the mean mass fractionation of these standards (FÅ 6 ± 0.7 ‰/amu) was used to correct the measured ^{53}Cr/^{52}Cr ratios in pallasite olivines. The standard ratios for Cr isotopes used in this study are 0.051859 (^{50}Cr/^{52}Cr) and 0.11346 (^{53}Cr/^{52}Cr) [7]. It should be recognized that the effects being sought are small and that the precision achievable by the current SIMS technique is limited. We believe that the results reported below are reasonable but in all cases, press on the limits of error.

A key to finding evidence for ^{53}Mn is identifying phases with high Mn/Cr ratios. Phosphates in pallasites can have high Mn/Cr [3], but all phosphates that we found have Mn/Cr < 20. Olivines in pallasites are distinctly zoned, with Cr decreasing and Mn increasing toward the edges of the crystals (Fig. 1). Previous reports have shown that this zoning is controlled by diffusion upon cooling [8,9,10]. The olivine zoning produced ^{55}Mn/^{52}Cr ratios ranging from ~10 in the cores up to ~ 100 at the edges. In contrast, the Norton County aubrite has a large alabandite grain (2×4 mm) with ^{55}Mn/^{52}Cr up to ~ 700.

Table 1 lists the Cr isotopic compositions. The Cr-rich phases, chromite, troilite, and daubreelite, have normal Cr isotopic composition. Olivines from three pallasites show variable Cr isotopic compositions, from normal to well-resolved ^{53}Cr* (up to δ^{53}Cr = 17.6 ± 8.1 ‰ ($2\sigma_{mean}$) in Brenham olivine). The ^{53}Cr excesses are generally correlated with Mn/Cr ratios. Together with data from chromite and troilite, these data define linear arrays with slopes of $(1.5 \pm 1.0)\times10^{-5}$, $(4.2 \pm 1.6)\times10^{-5}$, and $(1.2 \pm 0.6)\times10^{-5}$ for Albin, Brenham, and Springwater respectively, the latter consistent with the result of [3]. The contributions of cosmogenic ^{53}Mn and ^{53}Cr are < 0.2 ‰ in Brenham, which has an exposure age of 200 Ma [11], and are probably similarly negligible in the other pallasites. The Norton County alabandite shows no evidence of ^{53}Cr*. The inferred (^{53}Mn/^{55}Mn)$_o$ for this aubrite is $< 5\times10^{-7}$, which implies that Norton County may have formed 25 Ma after CAIs if ^{53}Mn was homogeneously distributed in the early solar nebula. This is consistent with the previously reported (^{53}Mn/^{55}Mn)$_o$ ($< 3\times10^{-6}$) in another aubrite, Peña Blanca Spring [12].

This work provides new evidence of widespread ^{53}Mn in pallasites. The inferred (^{53}Mn/^{55}Mn)$_o$ in these meteorites varies from $\sim2\times10^{-6}$ in Eagle Station [2] to $\sim4\times10^{-5}$ in Brenham. Taken at face value, these data appear to provide chronologic information about the pallasites. Eagle Station, an anomalous pallasite [6], has the lowest $(^{53}Mn/^{55}Mn)_o$ by almost an order of magnitude, implying that Eagle Station is "younger" than the other pallasites by 10-15 Ma. Pd-Ag data also indicate that Eagle Station is "younger" than Brenham by > 5 Ma [5]. The $(^{53}Mn/^{55}Mn)_o$ in Eagle Station is similar to those measured for several IIIAB iron meteorites [2,3]. The main group pallasites Albin, Brenham, and Springwater have much higher $(^{53}Mn/^{55}Mn)_o$ than Eagle Station and the IIIAB irons. The value for Eagle Station came from thermal ionization measurements of bulk olivine [2]. The high Mn/Cr phase in IIIAB irons is phosphate [3]. Thus, the data for Eagle Station and IIIAB irons measure bulk-rock fractionation events and may be considered as dating formation of these objects. Data for Albin, Brenham, and Springwater came from zoning profiles in olivine and date the cessation of Mn and Cr diffusion. It is interesting that Albin, Brenham, and Springwater have such high $(^{53}Mn/^{55}Mn)_o$. These ratios imply very early formation and cooling for main group pallasites. Such a history would be consistent with recent determinations of short cooling histories for pallasites [10]. The inferred $(^{53}Mn/^{55}Mn)_o$ for Brenham is surprisingly similar to the value obtained for Allende CAIs, 4.4×10^{-5} [1]

A word of caution is in order here. The experimental difficulties associated with making the instrumental fractionation correction introduce systematic uncertainties not covered by the reported errors. We have analyzed our data in several different ways, including direct comparison of $^{53}Cr/^{52}Cr$ in terrestrial and pallasitic olivine, and all give excesses of $^{53}Cr^*$ in pallasite olivine. The inferred $(^{53}Mn/^{55}Mn)_o$ range from ~50% higher than the reported numbers to ~40% lower. This additional uncertainty does not seriously affect the conclusions reached in this abstract, but further studies are clearly needed. Thermal ionization mass spectrometry of olivine may be useful in resolving this matter. A Mn/Cr ratio of 20, typical of the bulk olivine in pallasites, could exhibit ~15 ε ^{53}Cr excesses if these meteorites had an initial $^{53}Mn/^{55}Mn$ ratio of $\sim10^{-5}$. Such measurements would more directly reflect the formation age as they are less susceptible to the local diffusive equilibration.

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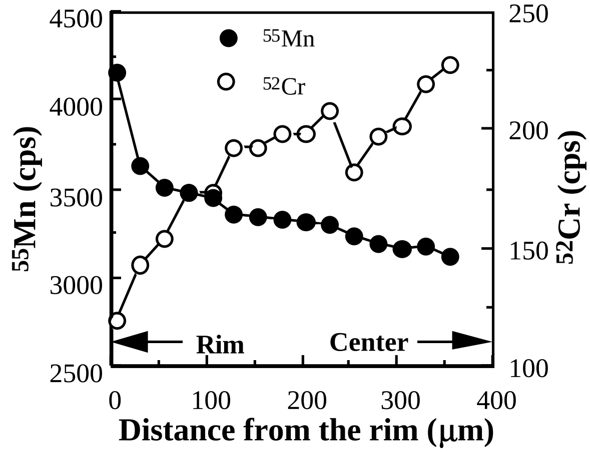

Fig. 1 Cr and Mn profiles in a Brenham olivine.

Table 1. ^{53}Cr excesses in pallasites and aubrite

	$\delta^{53}Cr$ (‰)	$2\sigma_{mean}$	$^{55}Mn/^{52}Cr$	$2\sigma_{mean}$
Albin $(^{53}Mn/^{55}Mn)_o=(1.5\pm1.0)\times10^{-5}(2\sigma_{mean})$				
Chromite	0.6	1.0	9×10^{-3}	4×10^{-4}
Olivine	2.9	6.5	12	0.6
Olivine	-0.2	7.1	34	1.7
Olivine	5.9	5.3	36	1.8
Olivine	9.6	6.6	57	2.8
Brenham $(^{53}Mn/^{55}Mn)_o=(4.2\pm1.6)\times10^{-5}(2\sigma_{mean})$				
Troilite	-2.0	2.5	0.06	0.003
Olivine	8.0	5.1	17	0.9
Olivine	5.4	5.5	30	1.5
Olivine	7.6	8.5	35	1.7
Olivine	17.6	8.1	41	2.1
Springwater $(^{53}Mn/^{55}Mn)_o=(1.2\pm0.6)\times10^{-5}(2\sigma_{mean})$				
Troilite	-1.6	1.9	0.19	0.01
Olivine	1.3	3.1	43	2
Olivine	6.0	6.1	48	2
Olivine	9.1	6.0	90	4
Norton County $(^{53}Mn/^{55}Mn)_o=(-9.0\pm4.9)\times10^{-7}(2\sigma_{mean})$				
Daubreelite	-0.6	1.0	0.03	0.001
Alabandite	-0.7	2.8	23	2
Alabandite	-2.4	5.6	123	15
Alabandite	-3.2	1.5	345	17
Alabandite	-10.1	13.9	706	36